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During the period of support of this grant there has been enormous activity. The principal investigator has had 14 research papers published and 8 papers accepted for publication; with still a number of papers ready to be submitted. There are a number of research directions and problems we are pursuing. These include the following. (i) Development of solutions to multidimensional nonlinear evolution equations of physical significance. Prototypes are the so-called Kadomtsev-Petviashvilli and Davey-Stewartson equations. We have found some new and important results. The nature of the boundary value problems and solutions of the equation in the so-called strong coupling limit have recently been uncovered. The role of the boundary conditions and a number of the essential differences between one and two)spatial) dimensional problems have been clarified. The role of the boundary conditions is important in the understanding of why highly localized multidimensional soliton solutions exist for one of the Davey-Stewartson (D-S) equations (i.e. DS-I but not DS-II). Specifically the soliton solutions correspond to a nontrivial mean field contribution at infinity. Considering the asymptotic

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description by which the D-S equations are derived, this means that energy must be inserted to the physical field at infinity. (ii) Solutions of discrete nonlinear evolutions, are numerical computation. In our studies we have found the following surprising situation. Namely associated with the integrable nonlinear Schrodinger equations are standard numerical schemes which exhibit at intermediate levels of mesh refinement a weak form of temporal chaos. Differnece schemes developed by Inverse Scattering Transform (IST) Methods do not exhibit this spurious chaos. All schemes agree when the mesh is sufficiently refined. (iii) Inverse problems associated with multidimensional problems. A key element in this work is the DBAR method developed by the principal investigator and his colleagues a few years ago. The method has been extended from the study of two dimensional invese problems, geophysics and acoustics. (iv) Cellular Automata and solitons. The principal investigator and his associates have been studying a class of cellular automata which admit solitons interaction. These systems are not reversible, which is quite a novel and interesting aspect. (v) Painlebe Equations. In our study of Painlebe equations we have developed a method to linearize these classical nonlinera ordinary differential equations. the linearization is provided by a system of Riemann-Hilbert boundary value problems which can be related to a system of linear integral equations. (vi) Semi-infinite and forced nonlinear evolution equations. Solution to these systems are under study and a connection between certain boundary value problems on the semi-infinite line and forced nonlinear wave equations has been found. (vii) Solutions to a class of nonlinear singular integro-differential equations have been developed. These include the well known Benjamin-Ono, Intermediate Long Wave and Sine-Hilbert equations. We have recently been studying multidimensional nonlinear singular integro-differential equations and have an number of interesting results. The broad attack is to understand the behavior and solutions of coherent structures in nonlinear equations arising in physical problems. The results obtained and interest by scientists in our work have motivated many of the studies. In what follows is a list of recent publications and our most recent proposal to AFOSR.

Final ~~Technical~~ Report AFOSR-TR- 1573

Submitted to

Air Force Office of Scientific Research

by

Principal Investigator

Mark J. Ablowitz

Department of Mathematics

and

Computer Science

Clarkson University

Potsdam, NY 13676

May 15, 1989

Overview

The current research funding has been used to support the research activities of Professor Mark J. Ablowitz and his associates. The principal investigator has been working in the general area of nonlinear wave propagation for over twenty years. The main focus of this work is the understanding of the nonlinear phenomena involved with the wave propagation arising in physical problems. The work has application to numerous areas of physics, engineering and mathematics. Applications include fluid dynamics, waves in stratified fluids, internal waves and wave excitation phenomena; numerical approximation and computation; nonlinear optics; and plasma physics. Moreover the study of solutions to some of the underlying nonlinear evolution equations has led naturally to the investigation and new results in the separate but closely related field of inverse scattering. Developments in both one and multidimensional inverse problems have been made.

During the period of support of this grant there has been enormous activity. The principal investigator has had 14 research papers published and 8 papers accepted for publication; with still a number of papers ready to be submitted. There are a number of research directions and problems we are pursuing. These include the following.

(i) Development of solutions to multidimensional nonlinear evolution equations of physical significance. Prototypes are the so-called Kadomtsev-Petviashvilli and Davey-Stewartson equations. We have found some new and important results. The nature of the

boundary value problems and solutions of the equations in the so-called strong coupling limit have recently been uncovered. The role of the boundary conditions and a number of the essential differences between one and two (spatial) dimensional problems have been clarified. The role of the boundary conditions is important in the understanding of why highly localized multidimensional soliton solutions exist for one of the Davey-Stewartson (D-S) equations (i.e. DS-I but not DS-II). Specifically the soliton solutions correspond to a nontrivial mean field contribution at infinity. Considering the asymptotic description by which the D-S equations are derived, this means that energy must be inserted to the physical field at infinity.

(ii) Solutions of discrete nonlinear evolution equations and numerical computation. In our studies we have found the following surprising situation. Namely associated with the integrable nonlinear Schrödinger equations are standard numerical schemes which exhibit at intermediate levels of mesh refinement a weak form of temporal chaos. Difference schemes developed by Inverse Scattering Transform (IST) Methods do not exhibit this spurious chaos. All schemes agree when the mesh is sufficiently refined.

(iii) Inverse problems associated with multidimensional problems. A key element in this work is the DBAR method developed by the principal investigator and his colleagues a few years ago. The method has been extended from the study of two dimensional inverse problems to n dimensions ($n>2$). In principal the method can be applied to inverse problems, geophysics and acoustics.

(iv) Cellular Automata and solitons. The principal investigator and his associates have been studying a class of cellular automata which admit solitons as special solutions. Very recently we have generalized these automata to two and three dimensions and have found instances of soliton interaction. These systems are not reversible, which is quite a novel and interesting aspect.

(v) Painlevé Equations. In our study of Painlevé equations we have developed a method to linearize these classical nonlinear ordinary differential equations. The linearization is provided by a system of Riemann-Hilbert boundary value problems which can be related to a system of linear integral equations.

(vi) Semi-infinite and forced nonlinear evolution equations. Solutions to these systems are under study and a connection between certain boundary value problems on the semi-infinite line and forced nonlinear wave equations has been found.

(vii) Solutions to a class of nonlinear singular integro-differential equations have been developed. These include the well known Benjamin-Ono, Intermediate Long Wave and Sine-Hilbert equations. We have recently been studying multidimensional nonlinear singular integro-differential equations and have a number of interesting results.

The broad attack is to understand the behavior and solutions of coherent structures in nonlinear equations arising in physical problems. The results obtained and interest by scientists in our work have motivated many of the studies. In what follows is a list of recent publications and our most recent proposal to AFOSR.

PUBLICATIONS

1. Solutions of Multidimensional Extensions of the Anti-Self-Dual Yang-Mills Equations, M.J. Ablowitz, D.G. Costa and K. Tenenblat, Stud. Appl. Math., 77:37-46, 1987.

2. Note on Solutions to a Class of Nonlinear Singular Integro-differential Equations, M.J. Ablowitz, A.S. Fokas and M.D. Kruskal, Phys. Lett. A., Vol. 120, 5 pp. 215-218, 1987.

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15. Strong Coupling Limit of Certain Multidimensional Nonlinear Wave Equations, M.J. Ablowitz and C.L. Schultz, Stud. in Appl. Math. 1-10, June 1989.

16. Numerically Induced Chaos in the Nonlinear Schrödinger Equation, B. Herbst and M.J. Ablowitz, Phys. Rev. Lett., Vol. 61, No. 18, 1989.

17. Interaction of Simple Particles in Soliton Cellular Automata, A.S. Fokas, E.P. Papadopoulou, Y.G. Saridakis and M.J. Ablowitz, INS#97, June 1988, to be published Stud. in Appl. Math.

18. Forced Nonlinear Evolution Equations and the Inverse Scattering Transform, A.S. Fokas and M.J. Ablowitz, INS#99, June 1988, to be published Stud. in Appl. Math.

19. Exact Solutions of Nonlinear Evolution Equation in the Strong Coupling Limit, C.L. Schultz and M.J. Ablowitz, to be published Proceedings for International Workshop on Nonlinear Evolution Equations: Integrability and Spectral Methods, Como, Italy, July 4-15, 1988.

20. Nonlinear Evolution Equations, M.J. Ablowitz, INS#111, to be published Proceedings for Singular Behavior and Nonlinear Dynamics held in Samos, Greece, August 1988.

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22. Nonlinear Evolution Equations, Inverse Scattering and Cellular Automata, M.J. Ablowitz, INS#114, to be published, Proceedigns on Solitons in Nonlinear Optics and Plasma Physics, Institute of Mathematics and Its Applications, IMA, Minneapolis, Minnesota, November 1988.

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24. On Numerical Chaos in the Nonlinear Schrödinger Equations, B. Herbst and M.J. Ablowitz, to appear Proceedings of Workshop on Complete Integrability, Orleon, France, INS#120, January 1989.

25. Rounding Error and the Loss of Spatial Symmetry Associated with Discretizations of the Nonlinear Schrödinger Equation, B.M. Herbst and M.J. Ablowitz, INS#122, April 1989.

26. Nonlinear Evolution Equations, Solitons, Strange Attractors and Cellular Automata, M.J.Ablowitz, B.M. Herbst and J.M. Keiser, INS#123, April 1989.

RENEWAL PROPOSAL

SUBMITTED TO

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

NONLINEAR WAVE PROPAGATION

PRINCIPAL INVESTIGATOR

MARK J. ABLOWITZ

PROGRAM IN APPLIED MATHEMATICS

UNIVERSITY OF COLORADO, BOULDER

BOULDER, COLORADO 80309

FEBRUARY 20, 1989

INDEX

1. Forward

The purpose for the continuation of this research funding is to support the research activities presently being carried out by Professor Mark J. Ablowitz and his associates. The principal investigator has been working in the general area of nonlinear wave propagation for over twenty years. The principal focus of this work is the understanding of the nonlinear phenomena involved with the wave propagation arising in physical problems.

In recent years the field of nonlinear wave propagation has witnessed considerable progress and conceptual breakthroughs and has provided valuable insights and results for mathematicians, physicists and engineers. Exact and approximate analytical solutions are particularly important to scientists as a means to understand the key elements governing physical problems. Direct applications include fluid dynamics, meteorology, nonlinear optics including fiber optic communications, lattice dynamics, plasma physics, numerical approximations and computation amongst others.

2. Overview

The central theme in this research is to understand the behavior and development of coherent structures in nonlinear problems and the solutions of the governing equations. The methods of analysis used are approximation methods such as asymptotic analysis, perturbation methods, numerical computation, and exact methods of solution. Especially interesting amongst the exact methods is the Inverse Scattering Transform (IST) and the associated concept of the soliton. IST employs methods of direct and inverse scattering in a novel way to solve certain underlying nonlinear evolution equations. The IST method brings together two important fields of study: (a) solutions of nonlinear evolution equations and (b) Inverse Scattering. Indeed applications of inverse scattering are themselves quite varied and significant. They include acoustic scattering, geophysics, radar imaging etc. Studies of IST have led to mew methods of solving inverse problems associated with differential and difference equations in both one and multidimensions.

In recent years a number of problems have been identified and solved. These include the following.

• Solutions of nonlinear multidimensional systems of physical significance. Prototypes are the Kadomtsev-Petviashvili and Davey-Stewartson equations. The nature of the boundary value problems and solutions of the equations in the strong coupling limit have recently been uncovered. The role of the boundary conditions is important in the understanding of why highly localized multidimensional soliton solutions exist for equations such as the Davey-Stewartson system.

3. Current and Proposed Research

In this section we shall briefly discuss some of the topics which we have studied along with the principal results and future directions.

(a) Multidimensional Nonlinear Evolution Equations, Solutions, and Physical Manifestations.

The Inverse Scattering Transform (IST) method has been well established as a powerful tool for solving nonlinear equations in one space and one time dimension. Essential for the applicability of this method is the association of a given nonlinear evolution equation with a linear scattering (spectral) problem. In reference [1] a review of many of these ideas is given with primary attention directed at one plus one dimensional (i.e. one space and one time dimension) problems. Indeed at the time [1] was written an effective procedure to solve the relevant two plus one dimensional problems was unknown, even though it had already been established that certain multidmensional nonlinear evolution equations were connected with multidimensional scattering problems [2].

In an important breakthrough we developed, implemented and characterized the IST technique for a class of physically interesting nonlinear evolution equations in two plus one dimension with suitable boundary values (decaying sufficiently fast at infinity). There are some reviews available regarding this new method and its applications (see for example, [3], [4]).

Some of the nonlinear multidimensional equations we have studied include the following:

(i) The Kadomtsev-Petviashvili (KP) equation:

$$(u_t+6uu_x+u_{xxx})_x + 3\sigma^2 u_{yy} = 0, \ \sigma^2 = \pm 1 \tag{1}$$

(ii) The Davey-Stewartson (DS) system:

$$\begin{aligned} iu_t + \sigma^2 u_{xx} + u_{yy} &= (\phi-|u|^2)u \\ \phi_{xx} - \sigma^2 \phi_{yy} &= \pm 2(|u|^2)_{xx}, \ \sigma^2 = \pm 1 \end{aligned} \tag{2}$$

(iii) The 3-Wave Interaction equations:

$$u_{it}+c_{ix}u_{ix}+c_{iy}u_{iy} = \gamma_i u_j^* u_k^*, \tag{3}$$

with i,j,k taking the values 1,2,3 permuted, c_{ix}, c_{iy}, γ_i are constant, u^* is the complex conjugate of u. The above equations arise in a number of important physical problems e.g. fluid dynamics, nonlinear optics, plasma physics etc. (see for example Ref. [5-8]. It should be pointed out that these equations are natural two dimensional generalizations of one dimensional equations which have broad physical significance. In particular the K-P equation generalize the Korteweg-deVries (KdV) equation; the Davey-Stewartson equations reduce to the ubiquitous nonlinear Schrodinger equation in the one dimensional limit, and the three wave interaction arises in a generic sense in both one and two dimensions reduction as well.

With regard to the Davey-Stewartson system, the equations (2) above, are in fact a special case of a more general system discussed in [5,7,8]:

$$\begin{aligned} iu_t + \sigma_1 u_{xx} + u_{xx} &= (\phi-|u|^2)u \\ \phi_{xx} + \frac{1}{a}\phi_{yy} &= -\frac{b}{a}(|u|^2)_{xx} \end{aligned} \tag{4}$$

σ_1,a,b constants. (4) reduces to (2) when we take $\sigma_1 = -1/a = \sigma^2 = \pm 1$ $b = 2/\sigma_2, \sigma_2 = \pm 1$. The generalized D-S system (4) is of considerable physical interest; it is the most natural two dimensional analogue of the one-dimensional nonlinear Schrodinger equation and as such has broad physical application. Depending on the values of σ ,a,b we have rich and varied behavior. This includes: IST reductions (i.e. equations (2)); self-focussing singularities (a special case of (4) is the extensively studied two dimensional nonlinear Schrodinger equation); instability of plane wave solitons; depending on the sign of a, there are a variety of interesting boundary value problems available. For example when $\sigma^2 = +1$ in (2) the mean term ϕ will not, in general, vanish as $r = \sqrt{x^2+y^2} \to \infty$ and it turns out that the equation can support exponentially decaying multidimensional soliton solutions. (This will be briefly discussed later in this section.)

In recent studies we have illustrated how the boundary values of ϕ can be critical in the solution of (2) and (4). In [9] we have solved equation (2) and given the action angle variables for the specific boundary value behavior corresponding to a DBAR limit of the inverse problem. In [10] we showed that the more general system (4) has a reduction in the strong coupling limit which is exactly solvable. This limit problem clearly shows how and why the boundary values of ϕ are critical in the solution process. The strong coupling limit of the Zakharov equations of plasma physics can be solved in a similar manner as well [11].

Besides illuminating the structure of a limiting class of solutions to these equations, preliminary studies indicate that the strong coupling limit will provide a useful vehicle to numerically solve the governing equations via the Fourier split-step method. We intend to study the numerical simulation of (4) in the near future. Moreover a natural question to ask is how does the various boundary value problems arise in physical problems. We have some results [12] and intend to continue our work in this direction.

It should be stressed that the system (4) has a generic physical manifestation. It arises in the study of weakly nonlinear two dimensional modulations of an underlying single phase wave train. In [8] we have shown that the self focussing phenomena, so widely studied for the two dimensional nonlinear Schrodinger problem [13-16], is relevant. Moreover we are considering new physical systems for which the system (4) is relevant and for which the phenomena of self-focussing can and should be observable.

With regard to the solution of (2) the IST method is relevant. In 1+1 dimension IST involves understanding and solving certain kinds of Riemann-Hilbert boundary value problems (RHBVP) the so-called "splitting" of analytic functions which govern the one dimensional direct and inverse scattering problems. For 2+1 dimensions the governing inverse problem is more difficult and the much more general technique, the DBAR method, must be used to formulate integral equations which serve to characterize and solve the underlying inverse problem and thereby solve the associated nonlinear evolution equations. We also note that for certain boundary

value problems the inverse problem reduces to the solution of a nonlocal RHBVP and can be viewed as a degenerate DBAR problem. In our earlier studies we were able to incorporate weakly decaying lump type solitons (i.e. solitons which decay in all directions) in the IST method and give them a spectral characterization [see 3,4]. Previously these lump type soliton solutions were outside the framework of the initial value problem and had only been found by direct methods. Of considerable interest are the exponentially decaying soliton solutions to the Davey-Stewartson system (2), recently found by Boiti, Leon, Martina and Pempinelli [17] for the Davey-Stewartson I system (eq. (2),$\sigma^2=+1$). In the context of the earlier discussion these solitons arise when the boundary values of the mean term ϕ do not decay at infinity. Fokas and Santini [18] have shown that these solutions can be incorporated into the usual IST scheme by suitably modifying the time dependence of the scattering data. We are studying these solutions both in the context of the way in which they arise in a physical problem involving the Davey-Stewartson system as well as applying these ideas to other nonlinear wave equations in multidimensions.

On still another front we are searching for integrable equations in higher dimensions (i.e. 3+1 dimensions). At the present time there are very few equations in higher dimensions which have mathematical and/or physical significance and for which the IST technique can be applied. Examples include the self dual Yang Mills equations, see for example [19,20], and the generalized sine-Gordon equation [21]. Unfortunately despite the relevance of these equations to mathematics and physics they do not provide the type of multidimensional n+1 dimensional structure which would serve to most naturally generalize the IST results in 1+1 and 2+1 dimensions.

(b) Multidmensional Inverse Scattering

It is significant that the inverse scattering analysis, described briefly in section (a) of this proposal can be applied to the study of n-dimensional inverse problmes see ref. [22-25]. Both scalar and first order systems of n-dimensional operators have been considered. The procedure is based upon the DBAR method and allows a systematic approach for finding linear integral equations which serve to reconstruct the underlying eigenfunctions and the potential. Importantly equations are developed which characterize the scattering data and allow an alternative and simpler approach to reconstruction of the potential, instead of the linear integral equations mentioned above. These characterization equations are quadratically nonlinear. As such one does not expect that the standard procedure of IST will apply with these higher dimensional scattering problems as the basic linear problem since the time evolution equations will necessarily have to satisfy the nonlinear characterization equations. This helps explain why so few non-linear evolutions or dimensions higher than 2+1 are known to be solvable by IST.

Applications of this idea are to the multidimensional stationary and nonstationary Schrodinger equation and the generalized AKNS system. It should be noted note that the inverse problem for the stationary Schrodinger equation has been discussed, via different methods by Faddeev [26] and Newton [27]. Recently Nachman and Lavine and Novikov and Henkin in [28] have analyzed the ideas presented in [22] for large data, in order to investigate the existence

of the solutions to the linear integral equations governing the relevant eigenfunctions. This is intimately connected with the notion of exceptional points of the homogeneous integral equation.

Future problems we intend to study include application of this idea to acoustic scattering and geophysics, and carry out a numerical study of the characterization equations as a means to develop concrete inverse scattering reconstructions of an underlying potential.

(c) Discrete Inverse Scattering Transform, Numerical Schemes and Numerically Induced Chaos.

It is significant that many of the concepts related to the inverse scattering transform apply to discrete nonlinear evolution equations. For example some well known examples are the Toda Lattice [29]

$$u_{n_{tt}} = e^{-(u_n - u_{n-1})} - e^{-(u_{n+1} - u_n)} \tag{5}$$

and the following discrete nonlinear Schrodinger equation DNLS [30]

$$iu_{n_t} = (u_{n+1} + u_{n-1} - 2u_n)/h^2 + u_n u_n^*(u_{n+1} + u_{n-1}) \tag{6}$$

(h is the mesh size). Here we shall discuss some aspects of the latter equation which we call the integrable DNLS equation. Indeed (6) can be solved both on the infinite interval [30] as well as the periodic interval [31].

A natural question to ask is whether equation (6) represents a good approximation to the NLS equation,

$$iu_t + u_{xx} + 2u^2u^* = 0 \tag{7}$$

In our recent studies [32,33] we have compared (6) to the straightforward discrete approximation

$$iu_{n_t} + (u_{n+1} + u_{n-1} - 2u_n)/h^2 + 2u_n^2 u_n^* = 0, \tag{8}$$

as well as to standard Fourier spectral schemes. The differential-difference schemes were solved using the Runge-Kutta-Merson routine in the NAG software library, with

sufficiently high accuracy so that the results were not consequences of the time integration. For certain initial values, (which induce the so-called Benjamin-Feir instability) standard discretizations that we used other than the integrable DNLS scheme (6) produced chaotic solutions for intermediate levels of mesh (mode) refinement. The chaos disappears as expected when the discretization is fine enough and convergence to a quasi-periodic solution is eventually obtained. The results for the integrable DNLS equation get better uniformly as the mesh is refined. It should be noted that discrete NLS equations have important physical applications in their own right (see for example ref. [34-35]). Preliminary calculations on a forced nonlinear Schrodinger equation studied by Bishop, Flesch, Forest, McLaughlin and Overman [36] also indicate that qualitative features of the numerical solutions differ substantially between the various methods when one integrates for long periods of time.

Even though the example discussed above is relatively simple, nevertheless if numerically induced chaotic motions can exist when simulating integrable P.D.E.'s such as the NLS equation, it becomes clear that one must be very careful when dealing with more complex flows (e.g. Rayleigh -Benard connection [37]). Moreover these results further underscore the importance of estimating the Fourier dimension of the underlying phase space of the differential equation (see for example [38]). We intend to pursue the above line of investigation, considering other nonlinear evolution equations,

different forcing and initial behaviors as well as developing an analytical understanding of why the chaotic motion appears in these schemes.

O still another front we have developed partial difference equations (i.e. numerical schemes) which are solvable by IST. An obvious application is to numerical simulations. Some years ago we succeeded in analytically developing such schemes [39]. These schemes can be shown to converge to a given nonlinear P.D.E. (which itself is solvable by inverse scattering) in the continuous limit. Moreover they have the nice property that they are neutrally stable, have exact soliton solutions and possess an infinite number of conserved quantities. In subsequent studies we have compared the practical numerical simulations of a given nonlinear P.D.E. (e.g. cubic nonlinear Schrodinger, KdV and MKdV) using traditional methods, with our newly developed schemes. Our schemes have proven to be extremely strong. The results are compiled in a sequence of papers [40-43]. This work is continuing and novel numerical techniques which serve to increase speed have been found; we are currently developing schemes for multidimensional problems as well as developing higher order accurate schemes. In the future, we hope to continue to assess the usefulness of various numerical schemes on important model nonlinear problems for both one and two spatial dimensional problems. We note also that interesting recent work on KdV type equations via finite elements has been performed in [44]. In the future we hope to carefully compare our schemes with these finite element schemes as well.

(d) Semi-infinite and Forced Nonlinear Evolution Equations

Despite the success of the IST method to solve initial boundary value problems in 1+1 on the infinite line $-\infty<x<\infty$, nevertheless the question of solving different boundary value problems remains elusive. One of the simplest such problems is the nonlinear Schrodinger equation (NLS) on the semi-infinite line, namely: equation (7) with the initial boundary values $u(x,0) = h(x)$, $u(0,t) = g(t)$, where $h(x)$ decays rapidly as $x\to\infty$ and the given functions $h(x)$, $q(t)$ have appropriate smoothness and satisfy a necessary compatibility to ensure the existence of a solution at $x=0,t=0$.

When $g(t) = 0$ early work [45] established that the IST method was applicable and reduced to the sine-transform solution. When $g(t)\neq 0$, one needs to find the proper nonlinear analogue of the sine transform with nontrivial boundary forcing. In recent work Fokas [46] has developed a method by which the evolution of the inverse scattering data in time obey nonlinear equations which in the linear limit properly reduce to known results (the sine transform). Presently we are studying the question of linearization of these nonlinear equations and extensions to other physically important models.

Recently we [47] have found that certain forcing functions of a distributional type for KdV and NLS satisfy similar time evolution equations for the scattering data as in the semi-infinite problem. We expect to study this problem in the small amplitude limit in order to describe the evolution of and generation of solitons due to external forcing. This problem has direct physical applications: e.g. moving pressure distributions in fluid flows [48].

(e) Solitons in Cellular Automata

In recent years there has been wide interest in the study of Cellular Automata (CA) - see for example [49]. CA's have been used to simulate intriguing and intricate patterns, the development of coherent structures, simulation of PDE's such as the Navier-Stokes equations and have been applied to a variety of physical phenomena. We have been studying a class of CA's termed Parity Rule Filter Automata first derived by a group of scientists at Princeton University [50]. This is a 1+1 dimensional CA which has a broad array of interesting particles and phenomena associated with it. In [50] via numerical simulation various interactions and initial value problems were considered; it was found that frequently the inherent particles behaved like solitons. In a subsequent paper [51] a numerical method to compute periodic particles was given and applications to computation were given.

In our recent work we have studied the Parity Rule Filter Automata analytically. In particular we have been able to give a straightforward analytical rule called the Fast Rule Theorem which is equivalent to this CA [52]. Using this rule we have been able to study the interaction of particles and give concrete statements regarding when these particles will behave like solitons [53]. Moreover we have studied the question of obtaining periodic particles by analytic means and have obtained linear difference equations which characterize them.

Future directions include the investigation of other types of Filter Automata in 1+1 dimensions with solitonic properties, and an extension of this concept to multidimensional Cellular Automata. We have already made progress in this direction.

(f) Physically Significant Singular Nonlinear Integro-Differential Equations and their Solutions

We have applied the IST to a class of nonlinear singular integro-differential equations. There are many physically important applications where such singular integro-differential equations arise,and the understanding of special cases where analytical solutions can be obtained is of considerable value. A physical application which has been both of practical and laboratory interest is long internal gravity waves in a stratified fluid. In fact there have been a number of recent discoveries of gigantic internal wave solitons in the ocean. These studies have been reported in the popular literature, e.g. Scientific American [54], Physics Today [55] and the New York Times [56]. However both the way in which it arises, and the relevant mathematics strongly suggest that many other applications will be found as well. In fact it has been shown that there are applications to shear flow problems [57].

An equation describing long internal gravity waves in an appropriate two layer media is the so-called intermediate long wave equation (ILW)

$$u_t+2uu_x+T(u_{xx}) + \frac{1}{\delta}u_x = 0 \tag{9}$$

where

$$T(u) = \fint_{-\infty}^{\infty} \left(- \frac{1}{2\delta}\right)\coth\left(\frac{x-\xi}{2\delta}\right)u(\xi)d\xi.$$

$\fint_{-\infty}^{\infty}$ represents the principal value integral and δ is a parameter. References [58,59] discuss the derivation of (9) in the context of internal waves. As $\delta\to 0$ we have the KdV equation

$$u_t+2uu_x + \frac{\delta}{3} u_{xxx} = 0, \tag{10}$$

whereas if $\delta\to\infty$ we have the so-called Benjamin-Ono (B-O) equation

$$u_t + 2uu_x + H(u_{xx}) = 0 \tag{11}$$

where $H(u) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{u(\xi)}{\xi - x}d\xi$ is the Hilbert transform of u.

Thus equation (10) contains as limiting forms both the KdV and Benjamin-Ono equations. The fact that (9) has multisoliton solutions [60,61] suggested to us that indeed (9) may be solvable by the Inverse Scattering Transform (IST). In fact in our studies we found [62],[63] a Bäcklund Transformation, a generalized Miura Transformation, soliton and rational solutions, interesting dynamical systems and a new type of scattering problem which allows the IST method to be applied. The scattering problem for (9) is interpreted as a differential RHBVP in strips of width 2δ. As $\delta\to 0$ it reduces (as it should) to the Schrödinger scattering problem relevant to KdV (10), and as $\delta\to\infty$ to a differential RHBVP in half planes. The latter is used to linearize the Benjamin-Ono equation (11). The method to solve (9) and its inverse problem was given in [64-65]. In the limit $\delta\to\infty$ the inverse scattering results reduce to those of the one dimensional Schrödinger scattering problem. The inverse scattering amounts to solving a RHBVP in the spectral parameter with a "shift". A certain discrete symmetry relation must be derived in order to obtain this RHBVP. On the other hand when $\delta\to\infty$ the discrete symmetry relation becomes continuous, and this gives rise to a nonlocal RHBVP as the inverse problem. The method of solution to (11) is given in [66]. Subsequently we were able to demonstrate how one can find the results for the Benjamin-Ono equation ($\delta\to\infty$) by taking a suitable limit of the intermediate equation [67]. It turns out that the Benjamin-Ono equation bears many similarities to multidimensional problems, specifically the Kadomtsev-Petviashvili equation. In some sense the nonlocality behaves like an extra spatial dimension.

In more recent studies we have found other interesting non-linear singular integro-differential evolution equations which fall into similar categories such as those discussed above. An important case is the so-called Sine-Hilbert equation: (note the analogy to the classical sine-Gordon equation)

$$Hu_t = \sin u \qquad (12)$$

Equation (12) is but one of a class of interesting nonlinear singular integro-differential equations which are solvable by IST. The novelty here is that the underlying scattering problem is a pure RHBVP and we have demonstrated possibility of having only bound states in the scattering theory and no continuous spectrum [68].

Still another type of solvable nonlinear singular integro differential equation is discussed in [69]. In the future we intend to study 2+1 dimensional nonlinear singular integro-differential equations. Certain equations have been reported in the literature, and the DBAR method appears to be well suited in order to obtain solutions.

(f) Nonlinear Optics, Perturbations and Applications

One of the first applications of inverse scattering was associated with the focussing and defocussing of light beams in a medium with a nonlinear index of refraction. Indeed the equation of motion in one dimension is governed by the cubic nonlinear Schrödinger (NLS) equation; Zakharov and Shabat [70] first solved this equation explicitly by the method of IST. As mentioned earlier, in section (a) of this proposal, the two spatial dimensional NLS equation has a self focussing singularity. The question of formation and local behavior of the singularity has been a continuing theme of investigation for almost twenty years (see for example ref. [13-16]). Given the basic physical derivation of the Davey-Stewartson (D-S) equations [7-8] one expects that the D-S equations will arise naturally in nonlinear optics as well. Moreover since they have a self-focussing singularity of a similar type to the 2DNLS equation and the fact that D-S reduces to 2DNLS as a special case, makes the analytical and numerical study of the D-S equations of considerable interest.

Another important application of nonlinear optics which has been carefully studied is coherent optical pulse propagation. These studies involve the interaction of intense light radiation with various external media. If the frequency of an impinging light wave is appropriate, then strongly resonant interactions between the light and the media can take place. A particularly simple asymptotic description is obtained by considering the media to be a so-called two level atom and taking the light beam to be governed by classical electrodynamics. Within this framework the resonant interaction of

intense light with matter can be treated; the governing equations in the theoretical model lead to another context in which solitons occur. Indeed this resonant situation and associated soliton phenomena has been observed experimentally and in numerical solutions of the governing equations [71-72]. This phenomena is commonly referred to as Self-Induced Transparency (S.I.T.). The asymptotically reduced equations of motion of S.I.T. are very special, i.e. it has been shown that these equations can be solved exactly by use of the Inverse Scattering Transform [73-74]. Specifically, the analysis demonstrates that arbitrary initial values break up into a sequence of coherent pulses which do not decay as they propagate, plus radiation which rapidly attenuates. These coherent pulses are the solitons. A review of some of this work can be found in [75].

A natural question is whether these solitons are stable under multidimensional perturbations. In ref. [76] we have shown that a certain type of soliton i.e. a "2π pulse" is, in fact, unstable to certain transverse perturbations. These results are consistent with numerical and experimental studies on the transverse effects in S.I.T. [77-78]. In [79] we showed that the breather soliton solution referred to as the "0π" pulse was also unstable to long transverse perturbations. These stability calculations naturally led us to study the more general question of adding perturbations to equations which admit solitons or even solitary waves as special solutions. We have found that many of these perturbation problems can be successfully treated by well known asymptotic methods [80]. We have compared our results to some of those in the literature which employ the Inverse Scattering Transform (see for example ref.

[81-83]. An advantage of the direct technique is that it also may be applied to problems which are not necessarily integrable and hence IST does not apply at first. This analysis allows us to consider the question of stability and perturbations to more general solutions of the equations of self-induced transparency as well as the stability of more complicated soliton modes.

Recently an important application of solitons and their perturbations has been discovered in the study of optical soliton transmission in glass fibers. Experimental and numerical studies have confirmed the existence and practical relevance of soliton propagation in optical fibers. (See for example: [84-87].) These studies have led to a number of theoretical papers in the U.S., U.S.S.R. and Japan and they have required the use and extension of the perturbation results described above (see for example ref. [1,79-83]. The theoretical analysis requires one to derive higher order perturbations of the nonlinear Schrödinger equation. Having these higher order perturbations in hand allows one to determine their effect on the soliton solutions, and their evolution properties in the optical fiber.

There are numerous applications of optical solitons, and the related theory opens up a vista of associated research problems and valuable areas of study. We intend to address the question of optical soliton propagation, periodic perturbative forcing in addition to higher order perturbations and their ramifications on the soliton propagation. This should shed additional light on the need for amplifiers and repeaters in the transmission problem. We also expect to consider related questions involving multidimensional perturbations.

(h) Nonlinear O.D.E.'s of Painlevé Type and their Solutions.

The development of the Inverse Scattering Transform has shown that certain nonlinear evolution equations possess a number of remarkable properties, including the existence of solitons, an infinite set of conservation laws, an explicit set of action angle variables, etc. In [90] it was demonstrated that there is a deep connection between these nonlinear partial differential equations (PDE's) solved by IST and nonlinear ordinary differential equations (ODE's) without movable critical points. Some definitions are as follows: a critical point is a branch point or an essential singularity in the solution of the ODE. It is movable if its location in the complex plane depends on the constants of integration of the ODE (an ODE without moveable critical points is said to be of Painlevé type, or simply P-type. In [90] we studied a number of nonlinear evolution equations solvable by IST and corresponding symmetry reductions for which the relevant ODE was of P-type.

We have exploited this connection in order to develop both solutions and asymptotic conection formulae to some of the classical transcendents of Painlevé [91] as well as others. The method to determine if an ODE is of P-type is a useful device for determininig the integrability of an ODE. For example in [92] using this idea we have derived a new explicit solution for the traveling waves of Fisher's equation. Indeed this method, which was used successfully in classical problems [93] has seen a recent revival of interest (for example see [94-95]. In particular we note the extension of the ODE concept to PDE's [96]. In recent years there have

been numerous research papers on these questions and it has attracted wide interest (for a partial review see [97]).
On the other hand there is also the important question of solving the underlying nonlinear ordinary differential equation.
In this regard one is interested in finding a method of linearization of the ODE corresponding to general initial conditions. In our studies we have extended [100] the work of Flaschka and Newell [99] for the second Painlevé equation and have recently obtained results for some of the other classical Painlevé equations; in particular we have found solutions to the classical Painlevé IV, V equations [100]-[101].

In the future we intend to consider a number of related questions such as the following.

Derivation of the complete connection formulae (i.e. the global connection of asymptotic states) for the interesting Painlevé equations. It should be mentioned that important work has already been accomplished in this direction (see for example [102]-[104]).
Continue to develop methods of solution (i.e. linearization) for all of the Painlevé equations and give an alternative proof that the underlying ODE's do in fact satisfy the Painlevé property; i.e. that they have no moveable branch points or essential singularities, regardless of initial conditions;

Consider the extension of the Painlevé test to nonlinear singular integro-differential equations. Although there have been some attempts to do this, we have found that the published work is not adequate.

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CURRENT SUPPORT AND PENDING APPLICATIONS

Principal Investigator - Mark J. Ablowitz

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RECENT PUBLICATIONS - M.J. ABLOWITZ

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Solitons, Inverse Problems and Nonlinear Equations, INS#118, February 1989, to be published Journal of Computational and Applied Mathematics.

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EXPERIENCE:

Instructor, Summer Session, M.I.T., 1970.
Teaching Assistant in Mathematics, M.I.T., 1967-1971.
Assistant Professor of Mathematics, Clarkson University, 1971-75.
Associate Professor of Mathematics, Clarkson University, 1975-76.
Visiting Professor of Applied Mathematics, Princeton University, 1977-78.
Professor of Mathematics, Clarkson University, 1976-79.
Professor and Chairman, Department of Mathematics and Computer Science, Clarkson University, 1979-1985.
Visiting Professor of Applied Mathematics, Princeton University, Spring Semester, 1984.
Dean of Science, Clarkson University, July 1, 1985 - present.

AWARDS:

Sloan Foundation Fellowship 1975-1977.
Clarkson Graham Research Award 1976.
John Simon Guggenheim Foundation Fellowship, 1984.
Co-director, Joint U.S.-U.S.S.R. Symposium on Soliton Theory, Kiev, 1979.
Selected by U.S. National Academy of Science for scientific exchange visit to USSR, October 1984.
Invited member, Institute for Theoretical Physics University of California at Santa Barbara, Spring 1985.

BOOKS:

Solitons and the Inverse Scattering Transform, with H. Segur; published by SIAM Studies in Applied Matheamtics, 1981.

Topics in Soliton Theory and Exactly Solvable Nonlinear Equations, Proceedings of 1986 Oberwolfach Conference, Oberwolfach W. Germany, Ed. M.J. Ablowitz, B. Fuchssteiner and M.D. Kruskal.

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25. The Inverse Scattering Transform - Continuous and Discrete and its Relationship with Painleve Transcendents, M.J. Ablowitz, Research Notes in Mathematics, 26, pp. 9-32, 1978, Pitman Publ.

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83. Note on Solutions to a Class of Nonlinear Singular Integro-differential equations, M.J. Ablowitz, A.S. Fokas and M.D. Kruskal, Phys. Lett. A., Vol. 120, 5 pp. 215-218, 1987.

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NONTECHNICAL ARTICLES:

Soviet and U.S. Ties in Science, New York Times, August, 1980.

GRANTS:

National Science Foundation	1972 - present	
Mathematics Section	1972-73:	P.I. M.J. Ablowitz, A.C. Newell
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INVITED PRESENTATIONS:

Rensselaer Polytechnic Institute, Mathematics Department, May, 1972.

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Massachusetts Institute of Technology, Mathematics Department, December, 1973.

Rensselaer Polytechnic Institute, Mathematics Department, March, 1974.

Invited Speaker: SIAM Fall Meeting on Nonlinear Wave Propagation, October, 1974.

Joint Seminar: University of Chicago-Northwestern University, November, 1974.

Rockefeller University, December, 1974.

McGill University, Mathematics Department, November, 1975.

Princeton University, Applied Mathematics Department, January, 1976.

University of Pittsburgh, Mathematics Department, March, 1976.

Massachusetts Institute of Technology, Mathematics Department, 10 Lectures on Nonlinear Wave Propagation, April-May, 1976.

University of Chicago, Geophysics Department, May, 1976.

University of Denver, Mathematics Department, May, 1976.

Nihon University, Physics Department, Tokyo, Japan, July, 1976.

Nagoya University Plasma Physics Institute, Najoya, Japan, July, 1976.

Kyoto University, Physics Department, Kyoto, Japan, July, 1976.

Ritsumeikan University, Mathematics and Physics Departments, Kyoto, Japan, July, 1976.

Osaka University, Mechanical Engineering Department, Osaka, Japan, July, 1976.

University of Rochester, Mathematics Department, April, 1977.

University of Rome, Mathematics Department, Rome, Italy, June, 1977.

Los Alamos Labs, Albuquerque, New Mexico, November, 1977.

Denver University, Mathematics Department, November, 1977.

New York University, Mathematics Department, February, 1978.

Princeton University, Applied Mathematics Department, April, 1978.

International Quantum Electrodynamic Conference, Atlanta, GA, May, 1978.

Princeton University, Plasma Physics Lab, May, 1978.

Syracuse University, A.M.S. Meeting, invited speaker, October, 1978.

Naval Research Laboratory, Fluid and Numerical Computations Group, December, 1978.

Physics Group, C.N.R.S. Saclay, France, December, 1978.

S.U.N.Y. Buffalo, Mathematics Department, April, 1979.

Catholic University, Conference on Inverse Scattering, invited speaker, May, 1979.

University of Rhode Island, Conference on Nonlinear Partial Differential Equations, June, 1979.

International Conference on Solitons, Jadwisin, Poland, August, 1979.

International Conference on Soliton Theory, Kiev, U.S.S.R., Part of a Joint U.S. - U.S.S.R. Academy of Sciences agreement, September, 1979.

New York University, Courant Institute of Mathematical Sciences, December, 1979.

Columbia University, Dept. of Mathematics, February, 1979.

Workshop on Nonlinear Evolution Equations and Dynamical Systems, Chania, Crete, July 9-23, 1980.

Remarks on Nonlinear Evolution Equations and the Inverse Scattering Transform, Banff Conference, Banff Alberta, Canada, August, 1980.

Brown University, Providence, Rhode Island, October, 1980.

University of Montreal, November, 1980.

University of Michigan, November, 1980.

Georgia Institute of Technology, December, 1980.

Washington, D.C., December, 1980.

York University, Toronto, Canada, March, 1981.

Workshop on Nonlinear Evolution Equations, Solitons and Spectral Methods, August 24-29, 1981, Trieste, Italy.

Workshop on Mathematical Methods in Hydrodynamics and Integrability in Related Dynamical Systems, La Jolla Institute, La Jolla, California, December 7-9, 1981.

York University, Physics Department, March, 1982.

Yale University, Mathematics Department, March, 1982.

Princeton University, Applied Mathematics Program, April, 1982.

Columbia University, Program in Applied Mathematics, April, 1982.

Solitons '82, Scott Russell Centenary Conference and Workshop, Edinburgh, Scotland, August, 1982.

Cornell University, Ithaca, NY, Wave Phenomena, Twenty-Fifth Annual Meeting of the Society for Natural Philosophy, September 22-25, 1982.

School and Workshop, Nonlinear Phenomena, November 29-December 17, 1982, Oaxtapec, Mexico.

Cornell University, Ithaca, NY, April 21, 1983.

S.U.N.Y. at Stony Brook, Department of Theoretical Physics, April 22-25, 1983.

2nd Workshop on Nonlinear Evolution Equations and Dynamical Systems Orthodox Academy of Crete, Chania, Crete, August 13-28, 1983.

2nd International Workshop on Nonlinear and Turbulent Processes in Physics, Kiev, USSR, October 10-25, 1983.

Fifth IMACS International Symposium on Computer Methods for Partial Differential Equations, Lehigh University, June 19-21, Bethlehem, Pennsylvania, 1984.

Princeton University, Department of Mathematics, March 22, 1984.

University of Rome, Rome, Italy, 6 lectures: May 1-30, 1984.

Landau Institute for Theoretical Physics, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R., October, 1984.

V.A. Steklov Mathematical Institute, Academy of Sciences of the U.S.S.R., Leningrad, U.S.S.R., October, 1984.

University of Tokyo, Institute of Physics, Tokyo, Japan, November 1-5, 1984.

Gakashuin University, Department of Physics, Tokyo, Japan, November 5, 1984.

Kyoto University, Physics department, Kyoto, Japan, November 7-8, 1984.

Kyushu University, Research Institute for Applied Mathematics, Fukuoka, Japan, November 9, 1984.

Miyazaki University, Miyazaki, Japan, November 12-14, 1984.

Ehime University, Department of Applied Mathematics, Ehime, Japan, November 14, 1984.

Hiroshima University, Department of Mathematics, Hiroshima, Japan, November 15, 1984.

Nagoya University, Department of Physics, Nagoya, Japan, November 19-21, 1984.

Kyoto Univesity, Kyoto, Japan, Attend RIMS meeting, November 26-28, 1984.

University of Brazilia. Brazilia, Brazil, 4 lectures, December 10-24, 1984.

Laboratory for Scientific Computation, Rio de Janiero, Brazil, December 14, 1984.

Workshop on NOnlinear Dynamical Systems: Integrability and Qualitative Behavior, University of Montreal, July 29-August 16, 1985.

University of Montreal, Department of Mathematics, November 4-5, 1985.

University of Brazilia, Brazilia, Brazil, January 6-19, 1986.

Workshop on Physical Applications of Nonliner Systems: Waves in Fluids and Plasmas, University of Montreal, May 5-9, 1986.

Mathematisches Forschungsinstitut Oberwolfach, W. Germany, July 26 - August 8, 1986.

Penn State, Department of Mathematics, September 17-19, 1986.

"Solitons", Winter School, Tiruchirapalli, India, January, 1987.

Institute for Mathematics and Its Applications, University of Minnesota, IMA Program in Inverse Problems, Minneapolis, Minnesota, January, 1987.

Virginia Polytechnic Institute, Department of Mathematics, Blacksburg, VA, February, 1987.

4th Workshop Nonlinear Evolution Equations and Dynamical Systems, June 11-25, 1987 Montpellier, France.

AMS Thirty-Fifth Summer Research Institute, Bowdoin College, Brunswick, Maine, July6-24, 1987.

Workshop on Nonlinear Waves held at the Institute for Applied Mathematics, University of Minnesota, Minneapolis, MInnesota, July 24-27, 1987.

National Science Foundation, Washington, DC October 9, 1987.

SIAM 35th Anniversary Meeting, Denver, Colorado, October 12-15, 1987.

Workshop on Integrable Systems and Applications, Ile d'Oleron, France, June 20-24, 1988.

Woarkshop on Nonlinear Evolution Equations: Integrability and Spectral Methods, Como, Italy, July 4-15, 1988.

Workshop on Singular Behavior and Nonlinear Dynamics, Samos, Greece, August 18-26, 1988.

Institute for Mathematics and its Applications, University of Minnesota, Minneapolis, MN, September 13-16 and November 7-11, 1988.

Workshop on Mathematical Methods in Plasma Physics, Cornell University, Ithaca, NY, October 20-23, 1988.

Columbia University, Department of Mathematics, New York, NY, October 17, 1988.

University of Colorado, Department of Mathematics, Boulder, CO, February 15, 1989.

Rutgers University, Department of Mathematics, New Brunswick, NJ, March 3, 1989, "Nonlinear Evoltuion Equations, IST and Cellular Automata.

TEACHING CREDENTIALS:

Courses Taught	Elementary Calculus Differential Equations Advanced Calculus for Engineers Modern Managerial Mathematics Introduction to Numberical Analysis Approximation Methods of Applied Mathematics Nonlinear Wave Motion Elementary Analysis Asymptotic and Perturbation Methods Methods of Applied Mathematics - Complex Analysis, Partial Differential Equations, Vector Calculus, etc.
Teaching Evaluation	I have been rated by students on a scale of 5. The average is approximately 4.5.

Ph.D. STUDENTS:

J. Ladik, Nonlinear Differential - Difference Equations, June, 1975, Clarkson University.

Y.C. Ma, Studies of the Cubic Schrodinger Equations, Princeton University, 1977. I was an informal advisor and reader of the thesis.

A. Ramani, On O.D.E.'s of Painleve Type, Princeton University, 1979. I was an informal advisor and reader of the thesis.

Y. Kodama, Perturbation and Stability Problems in Nonlinear Waves. Ph.D. 1979, Clarkson University.

T. Taha, Numerical and Analytical Aspects of Nonlinear Evolution Equations. Ph.D. 1982, Clarkson University.

P. Santini, Aspects of the Theory for Multidimensional Nonlinear Partial Differential Equations Solvable via the Inverse Scattering Transform. Ph.D., June, 1983, Clarkson University.

U. Mugan, On the Soliton of the Classical Equations of Painleve. Ph.D. August, 1986.

R. Balart, Mathematical Modeling of Directional Solidification in the Absence of Gravity, Ph.D., December, 1986.

POSTDOCTORAL ASSOCIATES:

J. Satsuma	1977-79	From:	Kyoto University,, Applied Mathematics Department, Kyoto, Japan.
		Present Address:	University of Tokyo, Mathematics Department, Tokyo, Japan.
Y. Kodama	1979-81	From:	Nagoya University, Physics Department, Nagoya, Japan.
		Present Address:	Ohio State, Department of Mathematics, Columbus, Ohio.
A. Nakamura	1981-82	From:	Osaka University, Physics Department, Osaka, Japan.
		Present Address:	Osaka University, Physics Department, Osaka, Japan.
D. Bar Yaacov	1982-86	From:	Yale University, Department of Mathematics, New Haven, Connecticut.
		Present Address:	Vassar College Department of Mathematics Poughkeepsie, NY 12601
P. Clarkson	1984-86	From:	Oriel College, Department of Mathematics Oxford, England
		Present Address:	The University of Birmingham Department of Mathematics Birmingham, England

MASTER'S STUDENTS:

Benjamin Funk, June 1972

COMMITTEES:

(a) National

National Science Foundation Postdoctoral Fellowships in Mathematical Sciences, 1978 - 1986.

Conference Board on Mathematical Sciences, Regional Conferences Panel, 1979, 1980.

National Science Foundation Mathematics Panel Workshop, International Section, September 8-10, 1985.

NATO Postdoctoral Fellowship Review Panel, December 12-14, 1985.

(b) Clarkson University

Computer Science Committee of the Mathematics Department, 1971-1973.

Undergraduate Committee of the Mathematics Department, 1972-1974.

Graduate Committee of the Mathematics Department of 1974-1978.

Research Committee of Clarkson University, 1977.

Tenure Committee of Clarkson University, 1978.

Faculty Senator of Clarkson University, 1978.

(c) New York State
Member of Technical Advisory Committee for the New York State proposal for the Superconducting Super Collider, 1987.

CONFERENCE ORGANIZATION:

Co-Director, Organizer of American Mathematical Society Summer Conference of Nonlinear Wave Motion, Clarkson University, July 1972.

Co-Director, Organizer of the Joint - U.S. - U.S.S.R. Academy of Sciences Meeting held in Kiev, U.S.S.R., September 1979.

Co-Organizer of the Summer Institute on Nonlinear Dynamical Systems held at the University of Montreal, July 29 - August 16, 1985.

Co-Organizer of the Workshop on Physical Applications of Nonlinear Systems to be held at the University of Montreal, May 5 - 9, 1986.

Co-Organizer of the Oberwolfach Conference on Solitons to be held at the Mathematical Research Institute, Oberwolfach, W. Germany, July 27 - August 2, 1986.

PROFESSIONAL AFFILIATIONS:

Tau Beta Pi, Engineering Honor Society
Sigma Xi
Society of Industrial and Appl. Math.
Math Association of America
American Mathematical Society

BIOGRAPHICAL LISTINGS:

Who's Who in Education
Who's Who in the East
Probably others

CONSULTING EXPERIENCE:

Polaroid Corporation: Numerical Computation of Fluid Flow. Mission Research Corporation, Washington, DC: Nonlinear Wave Theory.

EDITORIAL BOARDS:

Editorial Board:	Studies in Applied Mathematics 1983 - SIAM Journal in Applied Mathematics 1983 -
Associate Editor:	Journal of Mathematical Physics: 1976-1979.
Journal/Grant Reviewing:	Physical Review Phys. Rev. Lett. J. Math. Phys. S.I.A.M. J. of Applied Mathematics J. on Math. Analysis Studies in Applied Mathematics J. Fluid Mechanics Phys. of Fluids N.S.F. Grants - Math Nat. Acad. Sci. - Grants for U.S. Army A.F.O.S.R. Research Grants

CURRENT SUPPORT AND PENDING APPLICATIONS

Principal Investigator - Mark J. Ablowitz

Current Support

USAF, AFOSR-88-0073, "Nonlinear Wave Propagation," Amount of Award: $159,363; Time Period: 11/1/87-10/31/89; Time Commitment of PI: 2.75 summer months; Location of Research: Clarkson University, Potsdam, NY.

NSF, DMS-8803471, (w/A. Fokas, D. Kaup), "Nonlinear Wave Motion," Amount of Award: $15,500; Time Period: 7/01/88-12/31/89; Time Commitment of PI: None; Location of Research: Clarkson University, Potsdam, NY.

USNA, NOOO14-88-K-0447, (w/A. Fokas), "Nonlinear Waves and Inverse Scattering," Amount of Award: $30,000; Time Period: 7/1/88-12/31/89; Time Commitment of PI: .63 summer month; Location of Research: Clarkson University, Potsdam, NY.

Pending Applications

ANCA, "Physics (Science) at the Frontier - A Cooperative Program for Northern New York, Southern Quebec, Ontario," Amount Requested: $7,000; Time Period: 1/1/89-12/31/89; Time Commitment of PI: None; Location of Research: Clarkson University, Potsdam, NY.

This renewal proposal which is being submitted to USAF.